PB85-188159

Determination of Bendiocarb in Industrial and Municipal Wastewaters

Battelle Columbus Labs., OH

Prepared for

Environmental Monitoring and Support Lab.
Cincinnati, OH

Apr 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB85-188159

EPA/600/4-85/021
April 1985

DETERMINATION OF BENDIOCARB IN INDUSTRIAL AND MUNICIPAL WASTEWATERS

by

J.S. Warner, T.M. Engel and P.J. Mondron
Battelle Columbus Laboratories
Columbus, Ohio 43201

Contract No. 68-03-2956

Project Officer

Thomas Pressley

Physical and Chemical Methods Branch
Environmental Monitoring and Support Laboratory
Cincinnati, Ohio 45268

ENVIRONMENTAL MONITORING AND SUPPORT LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/4-85/021	2.
3. RECIPIENT'S ACCESSION NO. PB85 188159/AS	
4. TITLE AND SUBTITLE Determination of Bendiocarb in Industrial and Municipal Wastewaters	5. REPORT DATE April 1985
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) J.S. Warner, T.M. Engel and P.J. Mondron	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Battelle Columbus Laboratories 505 King Avenue Columbus, Ohio 43201	10. PROGRAM ELEMENT NO. CBEB1C
	11. CONTRACT/GRANT NO. 68-03-2956
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Monitoring and Support Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268	13. TYPE OF REPORT AND PERIOD COVERED Final Report 4/82 - 11/82
	14. SPONSORING AGENCY CODE EPA 600/6

15. SUPPLEMENTARY NOTES

16. ABSTRACT

A method was developed for the determination of bendiocarb in wastewaters. The method development program consisted of a literature review; determination of extraction efficiency for the compound from water into methylene chloride; development of a deactivated Florisil cleanup procedure; and determination of suitable liquid chromatographic analysis conditions.

The final method was applied to a relevant industrial wastewater in order to determine the precision and accuracy of the method. The wastewater was spiked with the compound at levels of 8.0 µg/L and 80 µg/L. Recovery for bendiocarb at the 8 µg/L level was 65 ± 24 percent. Recovery at the 80 µg/L level was 70 ± 4 percent. The method detection limit (MDL) for bendiocarb in distilled water was 1.8 µg/L. The MDL in wastewaters may be higher due to interfering compounds.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Distribute to Public	Unclassified	45
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Environmental measurements are required to determine the quality of ambient waters and the character of waste effluents. The Environmental Monitoring and Support Laboratory - Cincinnati, conducts research to:

- Develop and evaluate methods to measure the presence and concentration of physical, chemical, and radiological pollutants in water, wastewater, bottom sediments, and solid waste.

- Investigate methods for the concentration, recovery, and identification of viruses, bacteria and other microbiological organisms in water; and, to determine the responses of aquatic organisms to water quality.

- Develop and operate an Agency-wide quality assurance program to assure standardization and quality control of systems for monitoring water and wastewater.

- Develop and operate a computerized system for instrument automation leading to improved data collection, analysis, and quality control.

This report is one of a series that investigates the analytical behavior of selected pesticides and suggests a suitable test procedure for their measurement in wastewater. The method was modeled after existing EPA methods being specific yet as simplified as possible.

Robert L. Booth, Director
Environmental Monitoring and Support
Laboratory - Cincinnati

ABSTRACT

A method was developed for the determination of bendiocarb in wastewaters. The method development program consisted of a literature review; determination of extraction efficiency for the compound from water into methylene chloride; development of a deactivated Florisil cleanup procedure; and determination of suitable liquid chromatographic analysis conditions.

The final method was applied to a relevant industrial wastewater in order to determine the precision and accuracy of the method. The wastewater was spiked with the compound at levels of 8.0 µg/L and 80 µg/L. Recovery for bendiocarb at the 8 µg/L level was 65 ± 24 percent. Recovery at the 80 µg/L level was 70 ± 4 percent. The method detection limit (MDL) for bendiocarb in distilled water was 1.8 µg/L. The MDL in wastewaters may be higher due to interfering compounds.

This report was submitted in partial fulfillment of Contract No. 68-03-2956 by Battelle Columbus Laboratories under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from February 1, 1982 to April 30, 1982.

CONTENTS

Foreword iii
Abstract iv
Figures vi
Tables vii

1. Introduction 1
2. Conclusions 2
   - Extraction and Concentration 2
   - Cleanup 2
   - Chromatography 2
   - Validation Studies 2
3. Experimental 2
   - Extraction and Concentration 3
   - Cleanup 3
   - Chromatography 3
   - Validation Studies 3
4. Results and Discussion 4
   - Extraction and Concentration 5
   - Cleanup 5
   - Chromatography 5
   - Validation Studies 5

References 8
Appendix 10

A. Bendiocarb Method 639 11

FIGURES

Number		Page
1	HPLC-UV Chromatogram of 10 ng of Bendiocarb.	6
2	HPLC-UV Chromatogram of 600 ng of Bendiocarb	7
3	Analytical Curve for Bendiocarb.	9

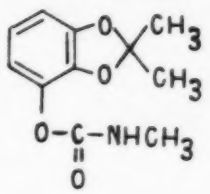
TABLES

Number		Page
1	Analytical Curve Data for Bendiocarb.	8

SECTION 1

INTRODUCTION

Bendiocarb (I) is an insecticide acting by cholinesterase inhibition and is effective as a contact and stomach poison. The acute oral LD50 for rats is 180 mg/kg, which indicates moderate toxicity.



(I)

The CAS registry number for bendiocarb is 22781-23-3 and the CAS name for bendiocarb is 2,2-dimethyl-1,3-benzodioxol-4-yl methylcarbamate. It has a melting point of 129-130 C. A synonym used for bendiocarb is "Ficam". A GC method of analysis using a modified alkali flame detector has been reported (1) as well as gas chromatographic (GC) pyrolysis and GC derivatization methods (2). It has been reported that bendiocarb is thermally unstable and an high performance liquid chromatographic (HPLC) method has been developed using reverse phase chromatography (3).

Bendiocarb can be extracted from water with methylene chloride. The selected approach to its determination in water included separatory funnel extraction from water with mehylene chloride, cleanup using Florisil chromatography, and analysis using HPLC with ultraviolet detection (UVD). Standard concentration techniques using Kuderna-Danish (K-D) equipment were used. The final method is included in Appendix A of this report.

SECTION 2

CONCLUSIONS

EXTRACTION AND CONCENTRATION

Bendiocarb can be extracted from water into methylene chloride with greater than 85 percent recovery using separatory funnel techniques. Use of K-D concentration equipment to perform extract concentrations did not significantly affect compound recoveries.

CLEANUP

Bendiocarb elutes from deactivated Florisil with greater than 80 percent recovery. This was an effective cleanup procedure for a relevant wastewater sample.

CHROMATOGRAPHY

Two HPLC columns, Spherisorb-ODS and Lichrosorb RP-2, were found to be acceptable for this application. The Spherisorb-ODS column was used as the primary column. The Lichrosorb RP-2 column was designated as the alternate column.

VALIDATION STUDIES

Recoveries of bendiocarb from distilled water in the 4 to 1000 µg/L concentration range averaged greater than 80 percent. The analytical curve constructed from this data was linear. The MDL in distilled water was 1.8 µg/L. Recoveries of bendiocarb from a relevant industrial wastewater at the 8 and 80 µg/L levels were 64 ± 24 and 70 ± 4 percent, respectively.

SECTION 3

EXPERIMENTAL

Studies were performed to determine if extractions with separatory funnels, cleanup by Florisil adsorption chromatography, concentration using K-D equipment, and analysis using HPLC with UVD would be applicable techniques for the determination of bendiocarb in water.

EXTRACTION AND CONCENTRATION

Extraction of bendiocarb from water by separatory funnel techniques was studied. One liter of distilled water was used. The distilled water was spiked with bendiocarb at the 20 µg/L and 100 µg/L levels. The samples were adjusted to pH 7 by the addition of 1 N sulfuric acid or 1 N sodium hydroxide and extracted three times with 60 mL each of methylene chloride. These studies were done in duplicate. The extracts were dried by passing them through 10 cm of anhydrous granular sodium sulfate and concentrated to two mL. The samples were solvent exchanged with acetonitrile by concentrating the sample to five mL after the addition of 15 mL of acetonitrile and analyzed by HPLC.

CLEANUP

A 10-gram Florisil column (deactivated with water saturated methylene chloride) was prepared and eluted with 100 mL of 50 percent methylene chloride in petroleum ether. The bendiocarb, 20 µg dissolved in one mL of methylene chloride, was added to the top of the column. The column was eluted with 50 mL portions of 50 percent methylene chloride in petroleum ether (F1), methylene chloride (F2), five percent acetone in methylene chloride (F3), 15 percent acetone in methylene chloride (F4), and 25 percent acetone in methylene chloride (F5). Each fraction was concentrated to 1 mL. The fractions were solvent exchanged to acetonitrile by reconcentrating them to 2 mL after the addition of 10 mL of acetonitrile.

CHROMATOGRAPHY

Two reversed phase HPLC columns were evaluated for the determination of bendiocarb: Spherisorb-ODS and Lichrosorb RP-2.

VALIDATION STUDIES

The MDL for bendiocarb was determined by analyzing seven replicate distilled water samples spiked at the 4 µg/L concentration level. The sample extracts were cleaned up using the Florisil cleanup procedure prior to analysis. The amounts recovered were determined by external standard calibration and the MDLs were calculated from these data.

Distilled water was also spiked in duplicate at the 4, 20, 100, 250, and 1000 µg/L concentration levels and recoveries of the bendiocarb were determined as described earlier. An analytical curve was generated by plotting the amount spiked into the samples versus the amount recovered from the samples.

A relevant industrial wastewater (obtained from a bendiocarb manufacturing site) was used for wastewater validation studies. Seven replicates of the wastewater were analyzed to determine the background levels. The wastewater was spiked with bendiocarb at the 8 and 80 µg/L concentration levels, processed and analyzed. Seven replicate extractions were performed at each concentration level.

SECTION 4

RESULTS AND DISCUSSION

EXTRACTION AND CONCENTRATION

Bendiocarb was extracted from water with greater than 85 percent recovery using separatory funnel techniques. Recovery of bendiocarb from water using separatory funnels were 82 and 96 percent at 20 µg/L and 91 and 93 percent at 100 µg/L. These data are the results of duplicate analyses.

CLEANUP

Bendiocarb eluted from deactivated Florisil in the 5 percent acetone in methylene chloride fraction (F3). Recovery of 20 µg of bendiocarb was 82 percent.

CHROMATOGRAPHY

Both the Spherisorb-ODS and Lichrosorb RP-2 columns were satisfactory for the determination of bendiocarb. The Spherisorb-ODS column was chosen as the primary column. The following conditions were used:

Column:	Spherisorb-ODS, 5 micron, 250 x 4.6 mm
Solvent:	40 percent acetonitrile/ 60 percent water
Flow:	1 mL/min
Detector:	UV @254 nm
Injection Volume:	5 µL
Retention Time:	9.3 min

A chromatogram obtained under these conditions is shown in Figure 1.

The Lichrosorb RP-2 column was chosen as the alternate column. The following conditions were used:

Column:	Lichrosorb RP-2, 5 micron, 250 x 4.6 mm
Solvent:	50 percent acetonitrile/ 50 percent water
Flow:	1 mL/min
Detector:	UV @254 nm
Injection Volume:	5 µL
Retention Time:	6.0 min

A chromatogram obtained under these conditions is shown in Figure 2.

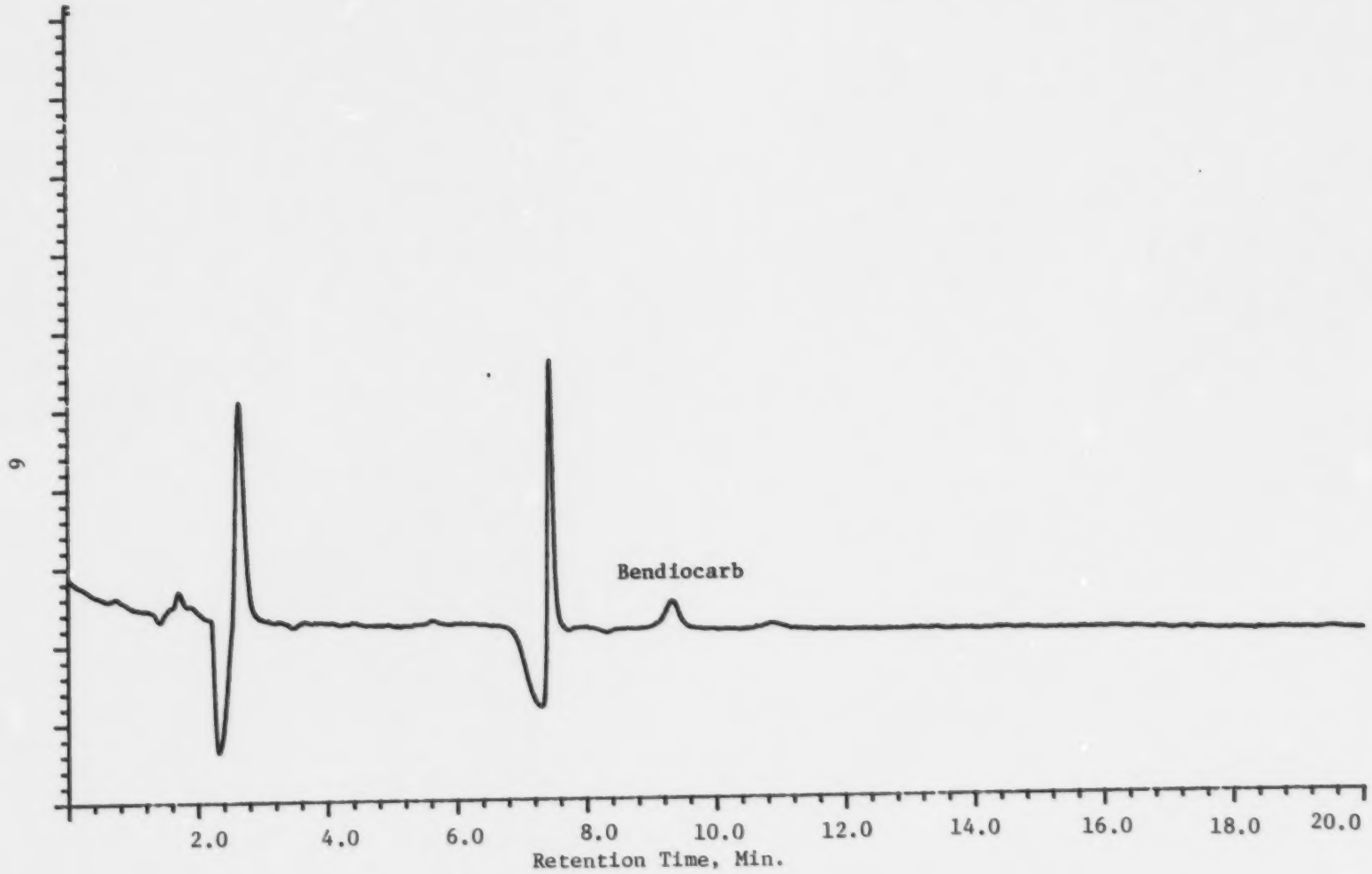


Figure 1. HPLC-UV Chromatogram of 10 ng of Bendiocarb (Column 1)

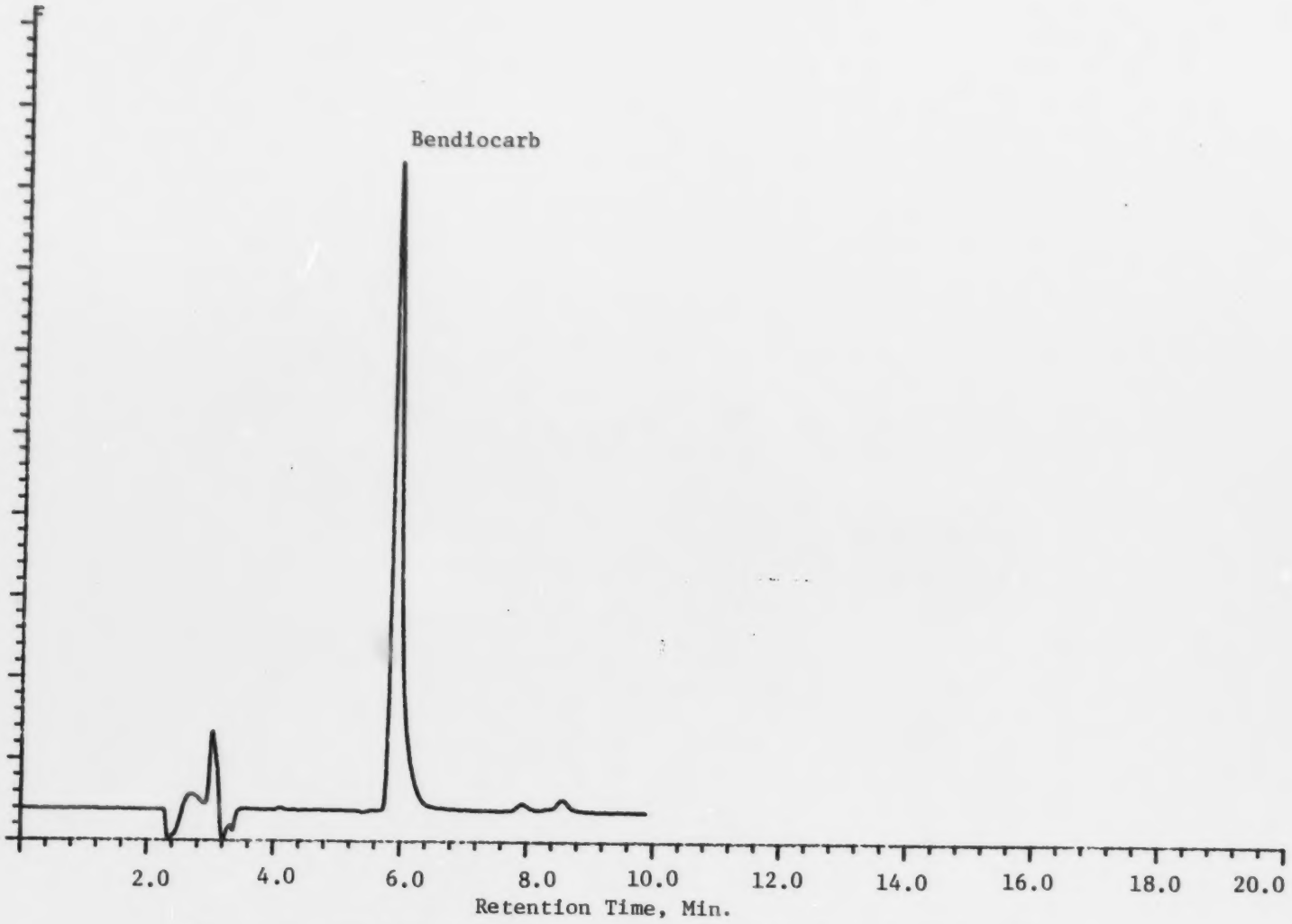


Figure 2. HPLC-UV Chromatogram of 600 ng of Bendiocarb (Column 2)

VALIDATIONS STUDIES

Recovery of bendiocarb from distilled water at the 4.0 µg/L level was 3.5 ± 0.6 µg/L. The MDL in distilled water was calculated to be 1.8 µg/L. Recoveries of bendiocarb from distilled water at the 4, 20, 100, 250, and 1000 µg/L levels were 3.5, 17, 82, 200, and 810 µg/L, respectively. These data were the averages of duplicate analyses. Individual data points are given in Table 1. The resultant analytical curve is shown in Figure 3.

TABLE 1. ANALYTICAL CURVE DATA FOR BENDIOCARB

Concentration, µg/L	Amount Recovered, µg/L(a)
4	3.3, 3.7
20	16, 18
100	78, 86
250	190, 210
1000	770, 850

(a) Results of duplicate analyses.

Recoveries of bendiocarb from a relevant wastewater at the 8 and 80 µg/L levels were 65 ± 24 percent and 70 ± 4 percent, respectively. These data were the averages of seven replicate analyses.

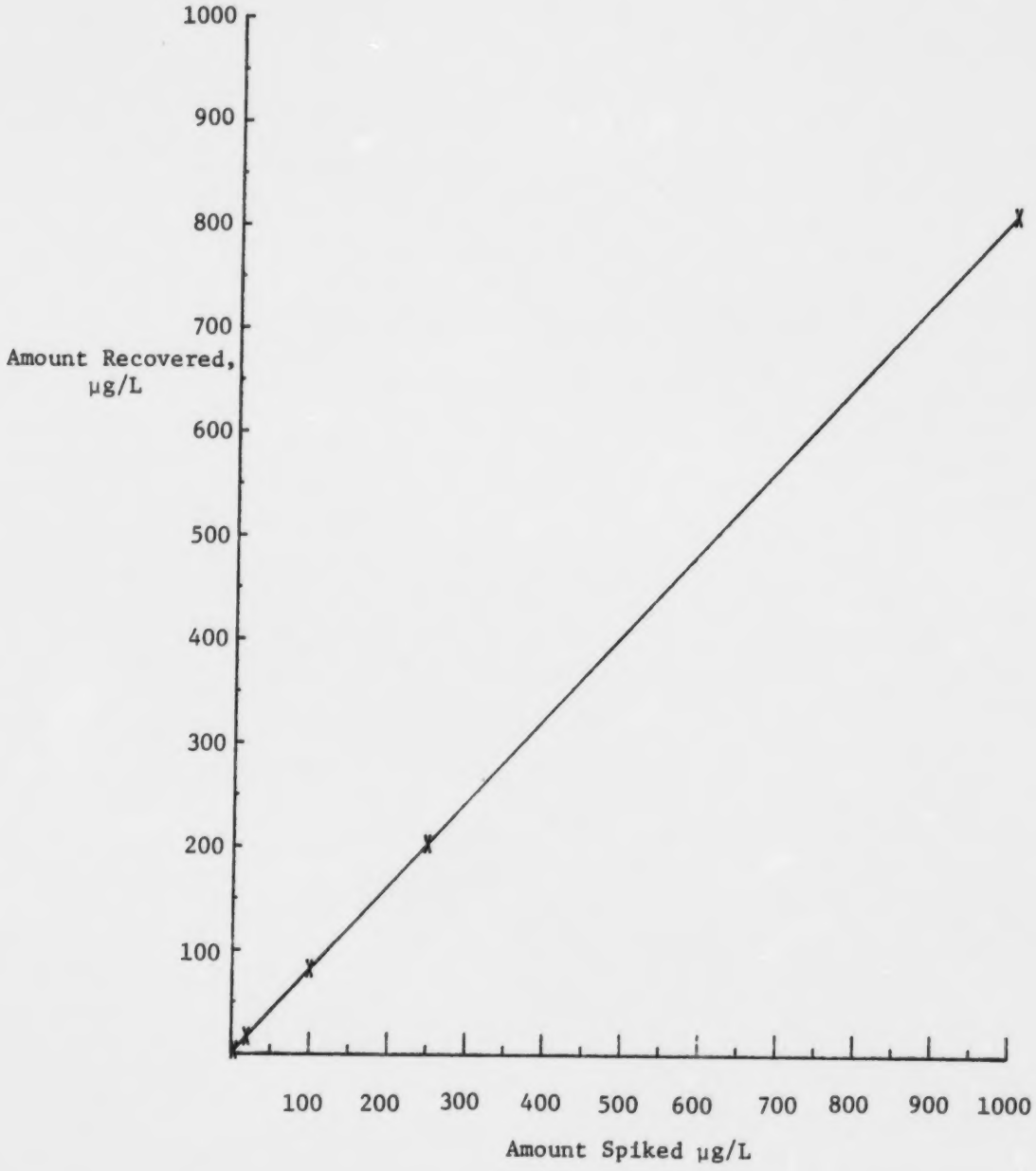


Figure 3. Analytical Curve for Bendiocarb

REFERENCES

1. Richie, A.R., S.R. Solly, and M.H. Clear. The Application of a Thermionic Detector to the Determination of Nitrogen-Containing Compounds on Thin-Layer Chromatograms. J. Chromatogr., 150(2):557-561, 1978.

2. Whitcoak, R.J., J.B. Reary, and K.C. Overton. Bendiocarb. In: Analytical Methods for Pesticides and Plant Growth Regulators, Voll. 10, G. Zweig and J. Sherma, eds. Academic Press, New York, San Francisco, and London, 1978. pp. 3-17.

3. Zehner, J.M., R.A. Simonaitis, and R.E. Bny. High Performance Liquid Chromatographic Determination of Bendiocarb on Wool. J. Assoc. Off. Anal. Chem., 63(1):47-48, 1980.

DETERMINATION OF BENDIOCARB IN MUNICIPAL AND INDUSTRIAL WASTEWATERS BY LIQUID CHROMATOGRAPHY
METHOD 639

1. Scope and Application

1.1 This method covers the determination of bendiocarb pesticide. The following parameter can be determined by this method:

Parameters	CAS No.
Bendiocarb	22781-23-3

1.2 This is a high performance liquid chromatographic (HPLC) method applicable to the determination of the compound listed above in municipal and industrial discharges as provided under 40 CFR 136.1. When this method is used to analyze unfamiliar samples for the compound above, compound identifications should be supported by at least one additional qualitative technique. This method describes analytical conditions for a second liquid chromatographic column that can be used to confirm measurements made with the primary column.

1.3 The method detection limit (MDL, defined in Section 15) for bendiocarb is listed in Table 1. The MDL for a speci[illegible] wastewater may differ from those listed, depending upon the nature of interferences in the sample matrix.

1.4 Any modification of this method beyond those expressly permitted, shall be considered a major modification subject to application and approval of alternate test procedures under 40 CFR 136.4 and 136.5.

1.5 This method is restricted to use by or under the supervision of analysts experienced in the use of liquid chromatography and in the interpretation of liquid chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method using the procedure described in Section 8.2.

2. Summary of Method

2.1 A measured volume of sample, approximately 1 liter, is solvent extracted with methylene chloride using a separatory funnel. The methylene chloride extract is dried and exchanged to acetonitrile during concentration to a volume of 2 mL or less. Liquid chromatographic conditions are described which permit the separation and measurement of the compounds in the extract by HPLC-UV. (1)

3. Interferences

3.1 Method interferences may be caused by contaminants in solvents, reagents, glassware, and other sample processing hardware that lead to discrete artifacts or elevated baselines in liquid chromatograms. All of these materials must be routinely demonstrated to be free from interferences under the conditions of the analysis by running laboratory reagent blanks as described in Section 8.5.

3.1.1 Glassware must be scrupulously cleaned. (2) Clean all glassware as soon as possible after use by rinsing with the

last solvent used in it. This should be followed by detergent washing with hot water and rinses with tap and distilled water. It should then be drained dry, and heated in a muffle furnace at 400°C for 15-30 minutes. Some thermally stable materials such as PCBs may not be eliminated by this treatment. Solvent rinses with acetone and pesticide quality hexane may be substituted for the muffle furnace heating. After drying and cooling, glassware should be sealed and stored in a clean environment to prevent any accumulation of dust or other contaminants. Store inverted or capped with aluminum foil.

3.1.2 The use of high purity reagents and solvents helps to minimize interference problems. Purification of solvents by distillation in all-glass systems may be required.

3.2 Matrix interferences may be caused by contaminants that are coextracted from the sample. The extent of matrix interferences will vary considerably from source to source, depending upon the nature and diversity of the industrial complex or municipality being sampled. Unique samples may require additional cleanup approaches to achieve the MDL listed in Table 1.

4. Safety

4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined; however, each chemical compound should be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory

is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material data handling sheets should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available and have been identified (3-5) for the information of the analyst.

5. Apparatus and Materials

5.1 Sampling equipment, for discrete or composite sampling.

5.1.1 Grab sample bottle - Amber glass, 1-liter or 1-quart volume, fitted with screw caps lined with Teflon. Foil may be substituted for Teflon if the sample is not corrosive. If amber bottles are not available, protect samples from light. The container and cap liner must be washed, rinsed with acetone or methylene chloride, and dried before use to minimize contamination.

5.1.2 Automatic sampler (optional) - Must incorporate glass sample containers for the collection of a minimum of 250 mL. Sample containers must be kept refrigerated at 4°C and protected from light during compositing. If the sampler uses a peristaltic pump, a minimum length of compressible silicone rubber tubing may be used. Before use, however, the compressible tubing should be thoroughly rinsed with methanol, followed by repeated rinsings with distilled water to minimize the potential for contamination of the sample. An integrating flow meter is required to collect flow proportional composites.

5.2 Glassware (All specifications are suggested. Catalog numbers are included for illustration only.)

5.2.1 Separatory funnel - 2000-mL, with Teflon stopcock.

5.2.2 Drying column - Chromatographic column 400 mm long x 10 mm ID with coarse frit.

5.2.3 Chromatographic column - 400 mm long x 19 mm ID with 250 mL reservoir at the top and Teflon stopcock (Kontes K-420290 or equivalent).

5.2.4 Concentrator tube, Kuderna-Danish - 10-mL, graduated (Kontes K-570050-1025 or equivalent). Calibration must be checked at the volumes employed in the test. A ground glass stopper is used to prevent evaporation of extracts.

5.2.5 Evaporative flask, Kuderna-Danish - 500-mL (Kontes K-570001-0500 or equivalent). Attach to concentrator tube with springs.

5.2.6 Snyder column, Kuderna-Danish - three-ball macro (Kontes K-503000-0121 or equivalent).

5.2.7 Snyder column, Kuderna-Danish - two-ball micro (Kontes K-569001-0219 or equivalent).

5.2.8 Vials - Amber glass, 5 to 10 mL capacity with Teflon lined screw-cap.

5.3 Boiling chips - approximately 10/40 mesh carborundum. Heat to 400°C for 4 hours or extract in a Soxhlet extractor with methylene chloride.

5.4 Water bath - Heated, capable of temperature control ($\pm$2°C). The bath should be used in a hood.

5.5 Balance - Analytical, capable of accurately weighing to the nearest 0.0001 g.

5.6 Liquid chromatograph - Analytical system complete with liquid chromatograph and all required accessories including syringes, analytical columns, detector and strip-chart recorder. A data system is recommended for measuring peak areas.

5.6.1 Pump - Isocratic pumping system, constant flow.

5.6.2 Column 1 - Reversed-phase column, 5 micron Spherisorb-ODS, 250 x 4.6 mm or equivalent.

5.6.3 Column 2 - Reversed-phase column, 5 micron Lichrosorb RP-2, 250 x 4.6 mm or equivalent.

5.6.4 Detector - Ultraviolet absorbance detector, 254 nm.

6. Reagents

6.1 Reagent water - Reagent water is defined as a water in which an interferent is not observed at the method detection limit of each parameter of interest.

6.2 Methylene chloride, methanol, acetonitrile, distilled-in-glass quality or equivalent.

6.3 Sodium sulfate (ACS) Granular, anhydrous; heated in a muffle furnace at 400°C overnight.

6.4 Sodium hydroxide, 1N - Prepare by adding 4 g of sodium hydroxide to distilled water and diluting to 100 mL.

6.5 Sulfuric acid, 1N - Prepare by adding 2.8 mL of concentrated sulfuric acid to distilled water and diluting to 100 mL.

6.6 Florisil - PR grade (60/100 mesh). Purchase activated at 1250°F and store in a brown glass bottle. To prepare for use, place 150 g in a wide-mouth jar and heat overnight at 160-170°C. Seal tightly with Teflon or aluminum foil-lined cap and cool to room temperature.

6.7 Stock standard solution (1.00 µg/µL) - Stock standard solution can be prepared from pure standard materials or purchased as certified solutions.

6.7.1 Prepare stock standard solutions by accurately weighing about 0.0100 grams of pure material. Dissolve the material in distilled-in-glass quality methanol and dilute to volume in a 10-mL volumetric flask. Larger volumes can be used at the convenience of the analyst. If compound purity is certified at 96% or greater, the weight can be used without correction to calculate the concentration of the stock standard. Commercially prepared stock standards can be used at any concentration if they are certified by the manufacturer or by an independent source.

6.7.2 Transfer the stock standard solution into Teflon-sealed screw-cap bottles. Store at 4°C and protect from light. Stock standard solution should be checked frequently for signs of degradation or evaporation, especially just prior to preparing calibration standards from them.

6.7.3 Stock standard solution must be replaced after six months or sooner if comparison with quality control check standards indicates a problem.

7. Calibration

7.1 Establish liquid chromatographic operating parameters equivalent to those indicated in Table 1. The liquid chromatographic system can be calibrated using the external standard technique (Section 7.2) or the internal standard technique (Section 7.3).

7.2 External standard calibration procedure:

7.2.1 For the compound of interest, prepare calibration standards at a minimum of three concentration levels by adding volumes of one or more stock standards to a volumetric flask and diluting to volume with acetonitrile. One of the external standards should be at a concentration near, but above, the method detection limit. The other concentrations should correspond to the expected range of concentrations found in real samples or should define the working range of the detector.

7.2.2 Using injections of 2 to 5 µL of each calibration standard, tabulate peak height or area responses against the mass injected. The results can be used to prepare a calibration curve for bendiocarb. Alternatively, the ratio of the response to the mass injected, defined as the calibration factor (CF), can be calculated at each standard concentration. If the relative standard deviation of the calibration factor is less than 10% over the working range, linearity through the origin can be assumed and the average calibration factor can be used in place of a calibration curve.

7.2.3 The working calibration curve or calibration factor must be verified on each working day by the measurement of one or more calibration standards. If the response for bendiocarb varies from the predicted response by more than ±10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve or calibration factor must be prepared.

7.3 Internal standard calibration procedure. To use this approach, the analyst must select one or more internal standards similar in

analytical behavior to bendiocarb. The analyst must further deomonstrate that the measurement of the internal standard is not affected by method or matrix interferences. Due to these limitations, no internal standard applicable to all samples can be suggested.

7.3.1 Prepare calibration standards at a minimum of three concentration levels for bendiocarb by adding volumes of one or more stock standards to a volumetric flask. To each calibration standard, add a known constant amount of one or more internal standards, and dilute to volume with acetonitrile. One of the standards should be at a concentration near, but above, the method detection limit. The other concentrations should correspond to the expected range of concentrations found in real samples, or should define the working range of the detector.

7.3.2 Using injections of 2 to 5 µL of each calibration standard, tabulate the peak height or area responses against the concentration for bendiocarb and internal standard. Calculate response factors (RF) as follows:

$$RF = (A_s C_{is})/(A_{is} C_s)$$

where:

A_s = Response for the compound to be measured.

A_{is} = Response for the internal standard.

C_{is} = Concentration of the internal standard in µg/L.

C_s = Concentration of the compound to be measured in µg/L.

If the RF value over the working range is constant, less than 10% relative standard deviation, the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to plot a calibration curve of response ratios, A_s/A_{is} against RF.

7.3.3 The working calibration curve or RF must be verified on each working day by the measurement of one or more calibration standards. If the response for bendiocarb varies from the predicted response by more than $\pm$10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve must be prepared.

7.4 Before using any cleanup procedure, the analyst must process a series of calibration standards through the procedure to validate elution patterns and the absence of interferences from the reagents.

8. Quality Control

8.1 Each laboratory using this method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of laboratory capability and the analysis of spiked samples as a continuing check on performance. The laboratory is required to maintain performance records to define the quality of data that is generated.

8.1.1 Before performing any analyses, the analyst must demonstrate the ability to generate acceptable accuracy and precision

with this method. This ability is established as described in Section 8.2.

8.1.2 In recognition of the rapid advances occurring in chromatography, the analyst is permitted certain options to improve the separations or lower the cost of measurements. Each time such modifications to the method are made, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 The laboratory must spike and analyze a minimum of 10% of all samples to monitor continuing laboratory performance. This procedure is described in Section 8.4.

8.2 To establish the ability to generate acceptable accuracy and precision, the analyst must perform the following operations.

8.2.1 Select a representative spike concentration for each compound to be measured. Using stock standards, prepare a quality control check sample concentrate in methanol 1000 times more concentrated than the selected concentrations.

8.2.2 Using a pipet, add 1.00 mL of the check sample concentrate to each of a minimum of four 1000-mL aliquots of reagent water. A representative wastewater may be used in place of the reagent water, but one or more additional aliquots must be analyzed to determine background levels, and the spike level must exceed twice the background level for the test to be valid. Analyze the aliquots according to the method beginning in Section 10.

8.2.3 Calculate the average percent recovery (R), and the standard deviation of the percent recovery (s), for the results.

Wastewater background corrections must be made before R and s calculations are performed.

8.2.4 Using the appropriate data from Table 2, determine the recovery and single operator precision expected for the method, and compare these results to the values measured in Section 8.2.3. If the data are not comparable, the analyst must review potential problem areas and repeat the test.

8.3 The analyst must calculate method performance criteria and define the performance of the laboratory for each spike concentration and parameter being measured.

8.3.1 Calculate upper and lower control limits for method performance as follows:

$$\text{Upper Control Limit (UCL)} = R + 3s$$

$$\text{Lower Control Limit (LCL)} = R - 3s$$

where R and s are calculated as in Section 8.2.3. The UCL and LCL can be used to construct control charts (6) that are useful in observing trends in performance.

8.3.2 The laboratory must develop and maintain separate accuracy statements of laboratory performance for wastewater samples. An accuracy statement for the method is defined as $R \pm s$. The accuracy statement should be developed by the analysis of four aliquots of wastewater as described in Section 8.2.2, followed by the calculation of R and s. Alternately, the analyst may use four wastewater data points gathered through the requirement for continuing quality control in

Section 8.4. The accuracy statements should be updated with this method. This ability is established as described regularly. (6)

8.4 The laboratory is required to collect in duplicate a portion of their samples to monitor spike recoveries. The frequency of spiked sample analysis must be at least 10% of all samples or one sample per month, whichever is greater. One aliquot of the sample must be spiked and analyzed as described in Section 8.2. If the recovery for a particular compound does not fall within the control limits for method performance, the results reported for that compound in all samples processed as part of the same set must be qualified as described in Section 13.3. The laboratory should monitor the frequency of data so qualified to ensure that it remains at or below 5%.

8.5 Before processing any samples, the analyst should demonstrate though the analysis of a 1-liter aliquot of reagent water that all glassware and reagents interferences are under control. Each time a set of samples is extracted or there is a change in reagents, a laboratory reagent blank should be processed as a safequard against laboratory contamination.

8.6 It is recommended that the laboratory adopt additional quality assurance practices for use with this method. The specific practices that are most productive depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be analyzed to monitor the precision of the sampling technique. When

doubt exists over the identification of a peak on the chromatogram, confirmatory techniques such as liquid chromatography with a dissimilar column, must be used. Whenever possible, the laboratory should perform analysis of standard reference materials and participate in relevant performance evaluation studies.

9. Samples Collection, Preservation, and Handling

9.1 Grab samples must be collected in glass containers. Conventional sampling practices (7) should be followed; however, the bottle must not be prerinsed with sample before collection. Composite samples should be collected in refrigerated glass containers in accordance with the requirements of the program. Automatic sampling equipment must be as free as possible of Tygon and other potential sources of contamination.

9.2 The samples must be iced or refrigerated at 4°C from the time of collection until extraction.

9.3 Adjust the pH of the sample to 6 to 8 with 1N sodium hydroxide or 1N sulfuric acid immediately after sampling.

10. Sample Extraction

10.1 Mark the water meniscus on the side of the sample bottle for later determination of sample volume. Pour the entire sample into a 2-liter separatory funnel. Check the pH of the sample with wide range pH paper and adjust to 7 with 1 N sodium hydroxide or 1 N H_2SO_4.

10.2 Add 60 mL of methylene chloride to the sample bottle, seal, and shake 30 seconds to rinse the inner walls. Transfer the solvent to

the separatory funnel and extract the sample by shaking the funnel for 2 min with periodic venting to release excess pressure. Allow the organic layer to separate from the water phase for a minimum of 10 min. If the emulsion interface between layers is more than one third the volume of the solvent layer, the analyst must employ mechanical techniques to complete the phase separation. The optimum technique depends upon the sample, but may include stirring, filtration of the emulsion through glass wool, centrifugation, or other physical methods. Collect the methylene chloride extract in a 250 mL Erlenmeyer flask.

10.3 Add a second 60-mL volume of methylene chloride to the sample bottle and repeat the extraction procedure a second time, collecting the extract. Perform a third extraction in the same manner and collect the extract.

10.4 Assemble a Kuderna-Danish (K-D) concentrator by attaching a 10-mL concentrator tube to a 250-mL evaporative flask. Other concentration devices or techniques may be used in place of the K-D if the requirements of Section 8.2 are met.

10.5 Pour the combined extract through a drying column containing about 10 cm of anhydrous sodium sulfate, and collect the extract in the K-D concentrator. Rinse the Erlenmeyer flask and column with 20 to 30 ml of methylene chloride to complete the quantitative transfer. Once the flask rinse has passed through the drying column, rinse the column with 30 to 40 mL of methylene chloride.

10.6 Add 1 or 2 clean boiling chips to the evaporative flask and attach a macro Snyder column. Prewet the Snyder column by adding

about 1 mL methylene chloride to the top. Place the K-D apparatus on a hot water bath, 60 to 65°C, so that the concentrator tube is partially immersed in the hot water, and the entire lower rounded surface of the flask is bathed with hot vapor. Adjust the vertical position of the apparatus and the water temperature as required to complete the concentration in 15 to 20 min. At the proper rate of distillation, the balls of the column will actively chatter but the chambers will not flood with condensed solvent. When the apparent volume of liquid reaches 1 mL, remove the K-D apparatus and allow it to drain and cool for at least 10 minutes.

10.7 Remove the macro-Snyder column and rinse the flask and its lower joint into the concentrator tube with 1 to 2 mL of methylene chloride. A 5-mL syringe is recommended for this operation. Add 1 or 2 clean boiling chips and attach a two-ball micro-Snyder column to the concentrator tube. Prewet the micro-Snyder column with methylene chloride and concentrate the solvent extract as before. When an apparent volume of 0.5 mL is reached, or the solution stops boiling, remove the K-D apparatus and allow it to drain and cool for 10 minutes.

10.8 Remove the micro-Snyder column and adjust the volume of the extract to 1.0 mL with methylene chloride. Stopper the concentrator tube and store refrigerated if further processing will not be performed immediately. If the extract is to be stored longer than two days, transfer the extract to a screw capped vial with a Teflon-lined

cap. If the sample extract requires no further cleanup, proceed with solvent exchange to acetonitrile as described beginning in Section 11.5. If the sample requires cleanup, proceed to Section 11.

10.9 Determine the original sample volume by refilling the sample bottle to the mark and transferring the water to a 1000-mL graduated cylinder. Record the sample volume to the nearest 5 mL.

11. Cleanup and Separation

11.1 Cleanup procedures may not be necessary for a relatively clean sample matrix. The cleanup procedure recommended in this method has been used for the analysis of various clean waters and industrial effluents. If particular circumstances demand the use of additional cleanup, the analyst must demonstrate that the recovery of each compound of interest is no less than 65%.

11.2 Slurry 10 g of Florisil in 100 mL of methylene chloride which has been saturated with reagent water. Transfer the slurry to a chromatographic column. Wash the column with 100 mL of methylene chloride. Use a column flow rate of 2 to 2.5 mL/min throughout the wash and elution profiles

11.3 Add the extract from Section 10.8 to the head of the column. Allow the solvent to elute from the column until the Florisil is almost exposed to the air. Elute the column with 50 mL of methylene chloride. Discard this fraction.

11.4 Elute the column with 50 mL of 5% acetone in methylene chloride. Collect this fraction in a K-D apparatus. Concentrate the column fraction to 1 mL as described in Sections 10.6 and 10.7.

11.5 Add 10-mL of acetonitrile to the concentrate along with 1 or 2 clean boiling chips. Attach a three-ball micro-Snyder column to the concentrator tube. Prewet the micro-Snyder column with acetonitrile and concentrate the solvent extract to an apparent volume of 1 mL. Allow the K-D apparatus to drain and cool for 10 minutes.

11.6 Transfer the liquid to a 2-mL volumetric flask and dilute to the mark with acetonitrile. Mix thoroughly prior to analysis. If the extracts will not be analyzed immediately, they should be transferred to Teflon sealed screw-cap vials and refrigerated. Proceed with the liquid chromatographic analysis.

12. Liquid Chromatography

12.1 Table 1 summarizes the recommended operating conditions for the liquid chromatograph. Included in this table are estimated retention times and method detection limits that can be achieved by this method. An example of the separations achieved by Column 1 and Column 2 are shown in Figures 1 and 2. Other columns, chromatographic conditions, or detectors may be used if the requirements of Section 8.2 are met.

12.2 Calibrate the liquid chromatographic system daily as described in Section 7.

12.3 If an internal standard approach is being used, the analyst must not add the internal standard to sample extracts until immediately before injection into the instrument. Mix thoroughly.

12.4 Inject 2 to 5 µL of the sample extract by completely filling the sample valve loop. Record the resulting peak sizes in area or peak height units.

12.5 The width of the retention time window used to make identifications should be based upon measurements of actual retention time variations of standards over the course of a day. Three times the standard deviation of the retention time for a compound can be used to calculate a suggested window size; however, the experience of the analyst should weigh heavily in the interpretation of chromatograms.

12.6 If the response for the peak exceeds the working range of the system, dilute the extract and reanalyze.

12.7 If the measurement of the peak response is prevented by the presence of interferences, further cleanup is required.

13. Calculations

13.1 Determine the concentration of individual compounds in the sample.

13.1.1 If the external standard calibration procedure is used, calculate the amount of material injected from the peak response using the calibration curve or calibration factor in Section 7.2.2. The concentration in the sample can be calculated as follows:

$$\text{Concentration, } \mu g/L = \frac{(A)(V_t)}{(V_i)(V_s)}$$

where:

A = Amount of material injected, in nanograms.

V_i = Volume of extract injected in µL.

V_t = Volume of total extract in µL.

V_s = Volume of water extracted in mL.

13.1.2 If the internal standard calibration procedure was used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.3.2 as follows:

$$\text{Concentration, } \mu g/L = \frac{(A_s)(I_s)}{(A_{is})(RF)(V_o)}$$

where:

A_s = Response for the compound to be measured.

A_{is} = Response for the internal standard.

I_s = Amount of internal standard added to each extract in µg.

V_o = Volume of water extracted, in liters.

13.2 Report results in micrograms per liter without correction for recovery data. When duplicate and spiked samples are analyzed, report all data obtained with the sample results.

13.3 For samples processed as part of a set where the laboratory spiked sample recovery falls outside of the control limits in Section 8.3, data for the affected compounds must be labeled as suspect.

14. Method Performance

14.1 The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.(8) The MDL concentrations listed in Table 1 were obtained using reagent water. (1) Similar results were achieved using representative wastewaters.

14.2 This method has been tested for linearity of recovery from spiked reagent water and has been demonstrated to be applicable over the concentration range from 10 x MDL to 1000 x MDL.

14.3 In a single laboratory, Battelle Columbus Laboratories, using spiked wastewater samples, the average recoveries presented in Table 2 were obtained. Seven replicates of each of two different wastewaters were spiked and analyzed. The standard deviation of the percent recovery is also included in Table 2. (1)

REFERENCES

1. "Development of Methods for Pesticides in Wastewaters," Report for EPA Contract 68-03-2956 (In preparation).

2. ASTM Annual Book of Standards, Part 31, D3694, "Standard Practice for Preparation of Sample Containers and for Preservation," American Society for Testing and Materials, Philadelphia, PA, p. 679, 1980.

3. "Carcinogens - Working with Carcinogens," Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Publication No. 77-206, August, 1977.

4. "OSHA Safety and Health Standards, General Industry," (29 CFR 1910), Occupational Safety and Health Administration, OSHA 2206 (Revised, January, 1976).

5. "Safety in Academic Chemistry Laboratories," American Chemical Society Publication, Committee on Chemical Safety, 3rd Edition, 1979.

6. "Handbook for Analytical Quality Control in Water and Wastewater Laboratories," EPA-600/4-79-019, U. S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory - Cincinnati, Ohio 45268, March, 1979.

7. ASTM Annual Book of Standards, Part 31, D3370, "Standard Practice for Sampling Water," American Society for Testing and Materials, Philadelphia, PA, p. 76, 1980.

8. Glaser, J. A. et al, "Trace Analysis for Wastewaters," Environmental Science and Technology, 15, 1426 (1981).

TABLE 1. CHROMATOGRAPHIC CONDITIONS AND METHOD DETECTION LIMITS

Parameter	Retention Time (min.) Column 1	Column 2	Method Detection Limit (µg/L)
Bendiocarb	9.3	6.0	1.8

Bendiocarb

Column 1 conditions: Spherisorb-ODS, 5 micron, 250 x 4.6 mm; 1 mL/min. flow; 40/60 acetonitrile/water.

Column 2 conditions: Lichrosorb RP-2, 5 micron, 250 x 4.6 mm; 1 mL/min. flow; 50/50 acetonitrile/water.

TABLE 2. SINGLE LABORATORY ACCURACY AND PRECISION(a)

Parameter	Average Percent Recovery	Relative Standard Deviation, %	Spike Level (µg/L)	Number of Analyses	Matrix Type(b)
Bendiocarb	65	35.6	8	7	1
	70	5.7	80	7	1

(a) Column 1 conditions were used.

(b) 1 = Relevant industrial wastewater.

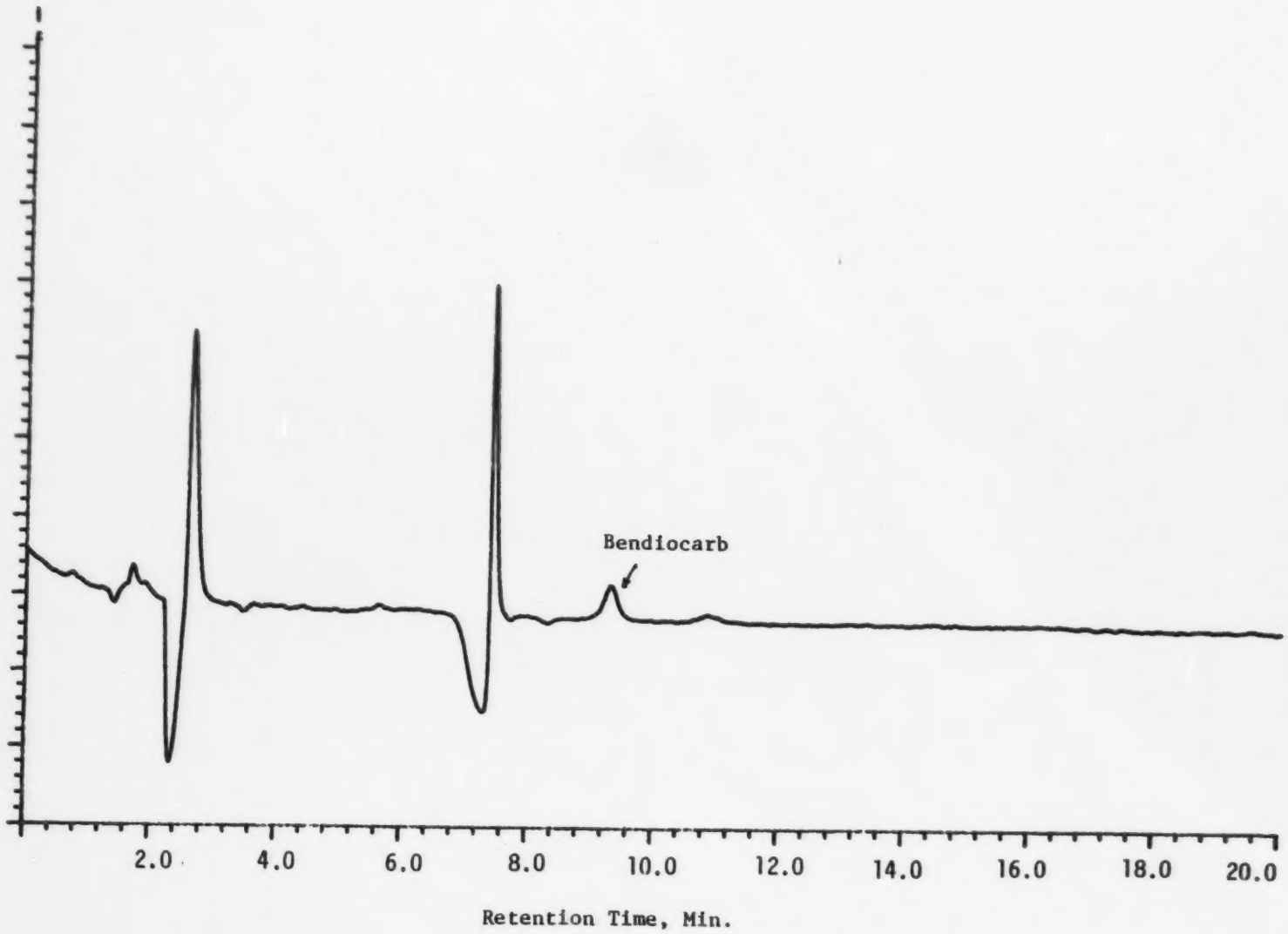


FIGURE 1. HPLC-UV CHROMATOGRAM OF 10 ng OF BENDIOCARB (COLUMN 1)

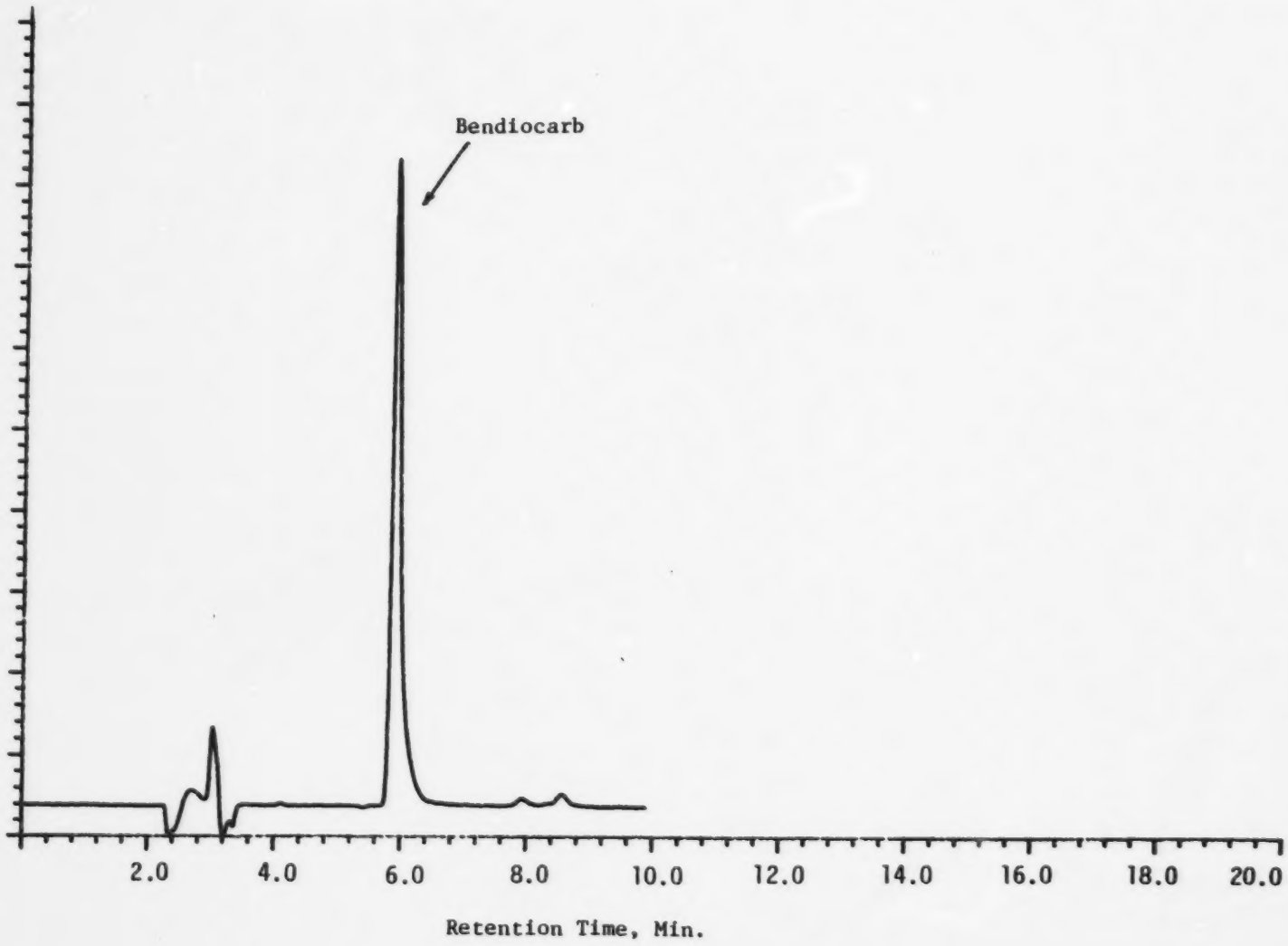


FIGURE 2. HPLC-UV CHROMATOGRAM OF 600 ng OF BENDIOCARB (COLUMN 2)